Natural Fracture Growth in Shales: Mechanisms and Implications for Assessment of Shale Resource Plays

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Natural fractures are relevant for shale-gas production either because they interact with hydraulic fracture treatments that are necessary for economic production, or because they contribute directly to storage or permeability. Interaction with hydraulic fracture treatments may serve to increase the effectiveness of the hydraulic fracture network, or could work against it. There are many factors governing whether the natural fracture network is advantageous or otherwise. Chief among these would be intensity and spacing of the natural fractures, their orientation with respect to S_{Hmax}, and the strength of the fracture plane relative to intact host rock.

A preliminary study of several shale-gas reservoirs showed that shales and their fracture systems are diverse (eg. Gale et al., 2007; Gale and Laubach, 2009; Gale and Holder, in press). These range from fractures developing shortly after deposition, when minimal compaction has occurred, to present-day fracture growth in the subsurface in tectonically active regions. Between these end members are the important group of fractures generated through hydrocarbon generation. We are now systematically characterizing the types of fractures present in the context of the burial and tectonic histories of the basin in which they are forming. Studies on the Barnett Shale and the New Albany Shale are the most advanced in this regard, and will be highlighted.

We tested the effect of calcite-sealed fractures on tensile strength of shale with a bending test. Samples containing natural fractures have half the tensile strength of those without and always break along the natural fracture plane. In Barnett shale examples the junction between the fracture-wall rock and cement is weak because the dominant calcite cement grows mostly over non-carbonate grains and there is no chemical bond between cement and wall rock. Thus, even completely sealed fractures are prone to reactivation. We examine the range of common fracture cements and host rock compositions in an effort to predict under which circumstances the fractures are likely to be weakest.

Natural fracture growth in shales is likely to be subcritical. The subcritical crack index is a rock property that can be used to predict facture clustering in geomechanical modeling (Holder at al., 2001; Olson, 2004). We have measured the subcritical crack index for several gas shales. The index is generally high for Barnett Shale, in excess of 100, although it does show variability with facies (Gale and Holder, 2008). By contrast, subcritical indices in the New Albany Shale are much lower, and also show considerable variability (Fidler, unpublished data). Barnett Shale subcritical indices suggest high clustering whereas New Albany Shale subcritical indices suggest fractures are likely to be more evenly spaced, with spacing related to mechanical layer thickness. We are investigating the variability in subcritical index in shale and how it might tie to other rock properties.

One new direction of our work is to gain understanding of the fundamental processes controlling fracture propagation in shales. In sandstones and carbonates the phenomenon of subcritical failure driven by chemical processes at the crack tip has been well documented (Atkinson, 1984; Rijken, 2005). In sandstones the hydrolytic weakening of quartz is thought to play a major role, while in carbonates there may be a solubility enhancement. The mechanism by which subcritical growth may occur in shales, which are finer grained and have greater clay and organic contents, is less well understood. We will use thin section analysis of tested samples to learn more about fracture propagation in shale.

References

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